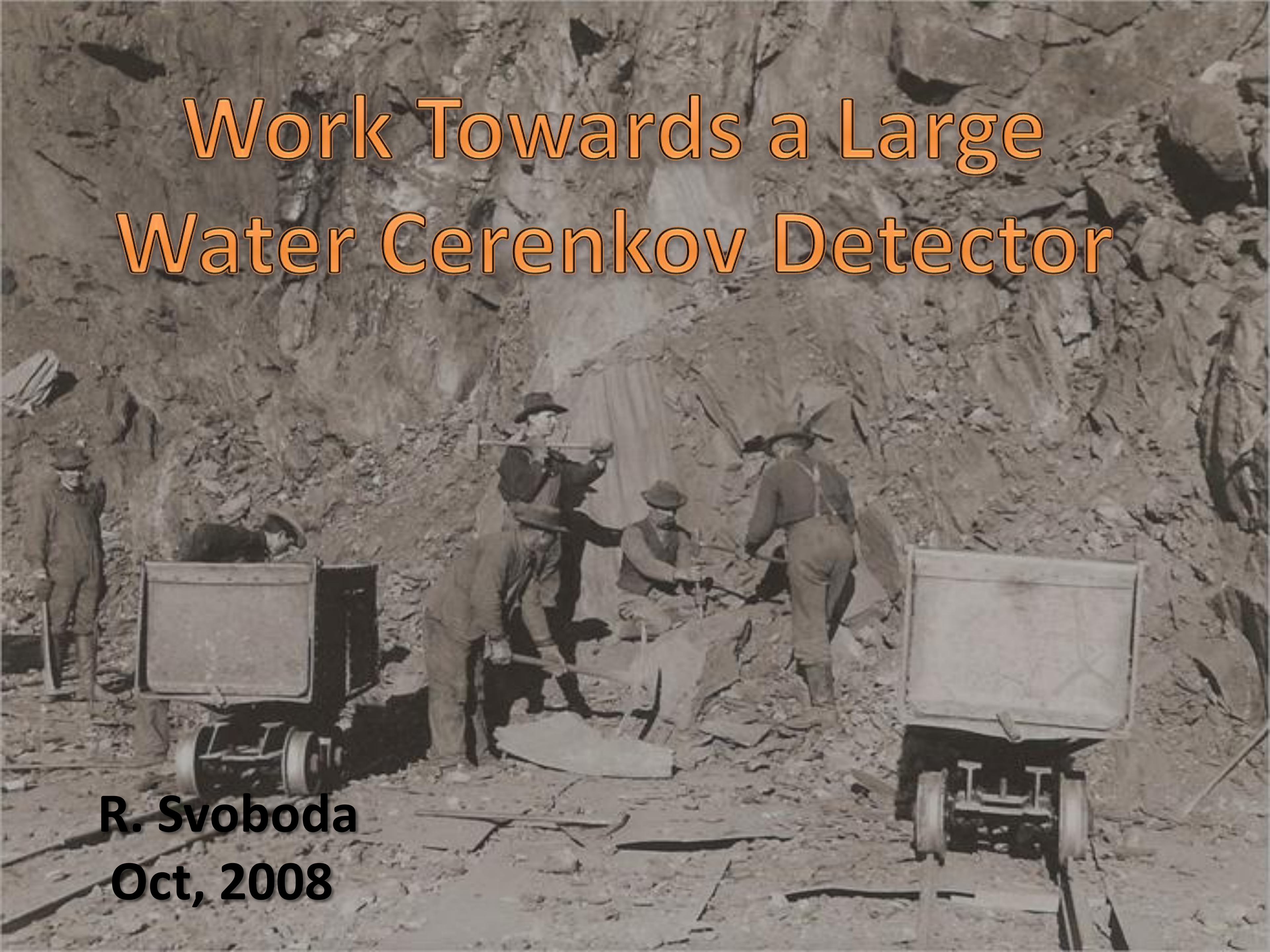
Work Towards a Large Water Cerenkov Detector



R. Svoboda

Oct, 2008

Mature Detector Technology

- IMB, Kamiokande, Super-K, SNO(D2O), miniBooNE (oil)
- "Mature" = 3/5 did not have serious accident
- We know some of the major problems that can cause a disaster
- We know what to do to improve with little technical or schedule risk

Water Cerenkov Joins Ranks of Other Boring Detector Technologies!

- Liquid Scintillator (Nova, Daya Bay, Double Chooz, Borexino, KamLAND, LENA)
- Silicon Detectors (CDF, CMS, ATLAS, PHENIX,…)
- Plastic Scintillator/Absorber (MINOS, K2K, T2K, ATLAS, CMS)
- Drift Tubes (CMS
- RPC (CMS, BELLE, Daya Bay)
- …

How can we improve?

- Bring down cost
- improve sensitivity
- improve electronics
- improve PMT response
- ensure implosion hardness
- improved analysis and simulation
- new photosensors (more tentative)

Gadolinium Doping

- sensitivity to neutron capture via 8 MeV gamma cascade (see M.Vagins, NNN08)
- Relic Diffuse SN flux (see talk at this conference)
- neutron tagging for proton decay background
- neutron tagging for low energy QE selection
- Challenge: water transparency, material compatibility

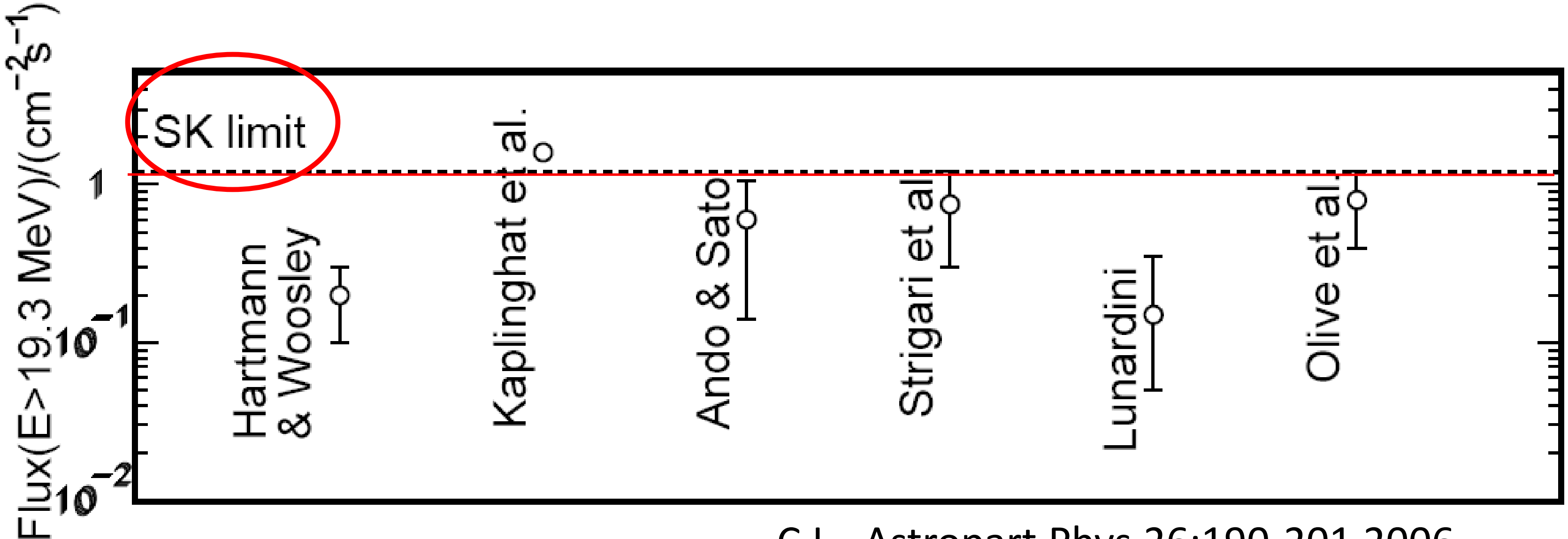
(10-20) x SK : event rate

- Exposure 1.6 Mton x year
  - e.g., 0.2 Mt for 8 years
  - Threshold 11.3 MeV, 100% efficiency

SN1987A-motivated (conservative)	Model-motivated (generic)	Max. allowed by SK limit
~22-128	~250	…

C.L., Astropart.Phys.26:190-201,2006, Fogli et al. JCAP 0504:002,2005, Volpe & Welzel, 2007, C.L. & O.L.G. Peres, to appear soon.

Potential Discovery for DUSEL

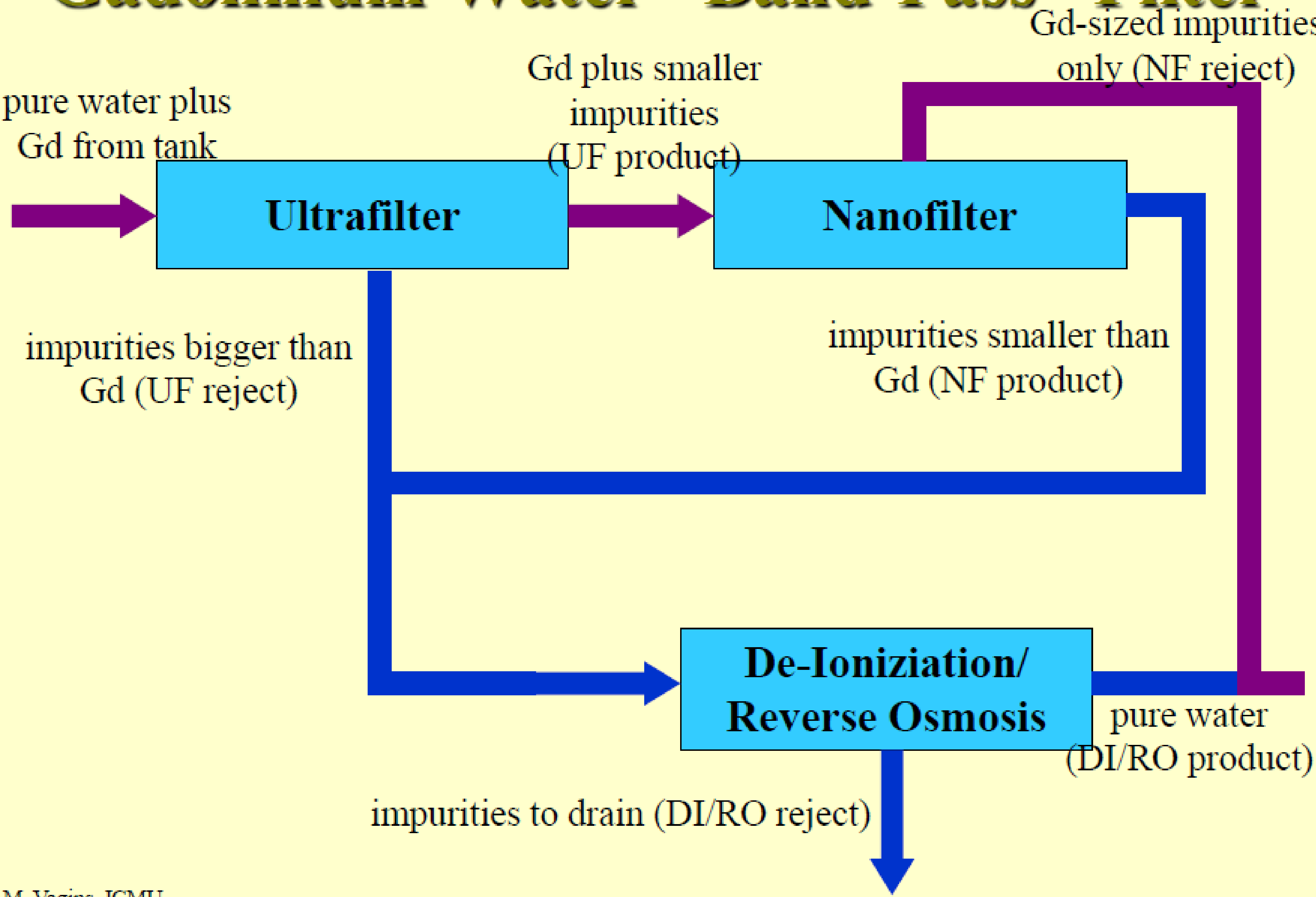


C.L., Astropart.Phys.26:190-201,2006

- Depends on stellar formation rate at z>0.5
- Test collapse models without waiting for galactic SN

C.Lunardini

Gadolinium Water "Band-Pass" Filter

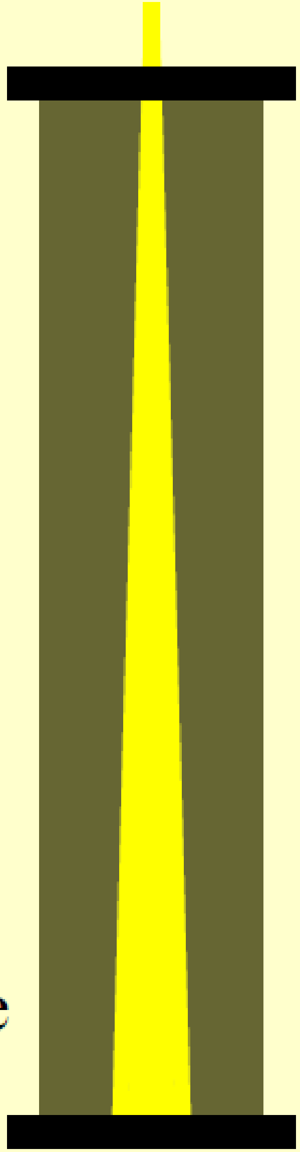


M. Vagins, ICMU

$Gd_2(SO_4)_3$ Filtering Progress

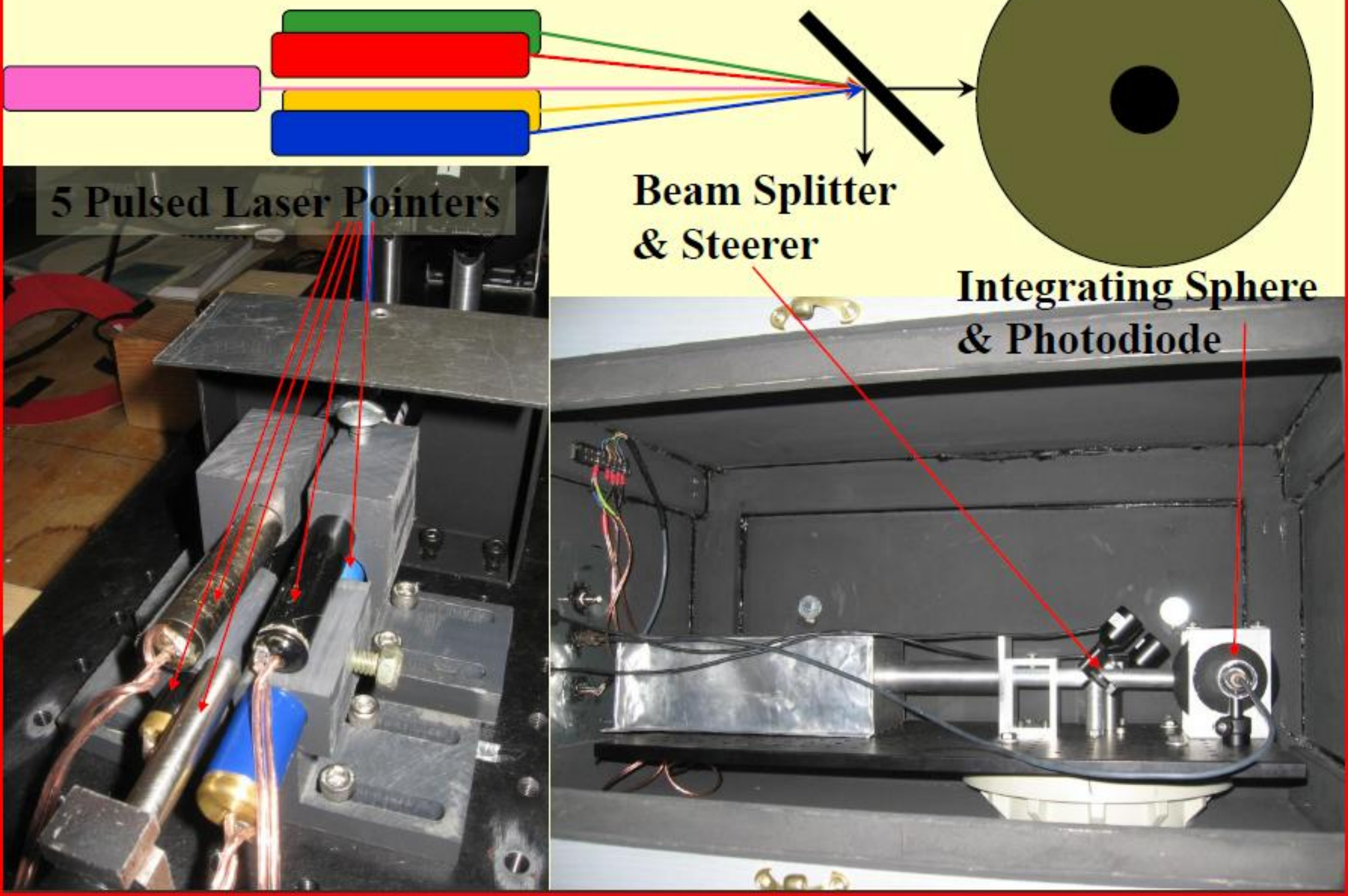
- took data with ultrafilter and two types of nanofilters
- basic principle is sound
- UF passed ~100% of $Gd_2(SO_4)_3$
- NF rejected >98% of $Gd_2(SO_4)_3$
- next: try multiple stages of NF; clean up product with RO units (before 2009)
- next: measure water transparency of $Gd_2(SO_4)_3$ (before 2009)

Check Water Transparency of System with IDEAL



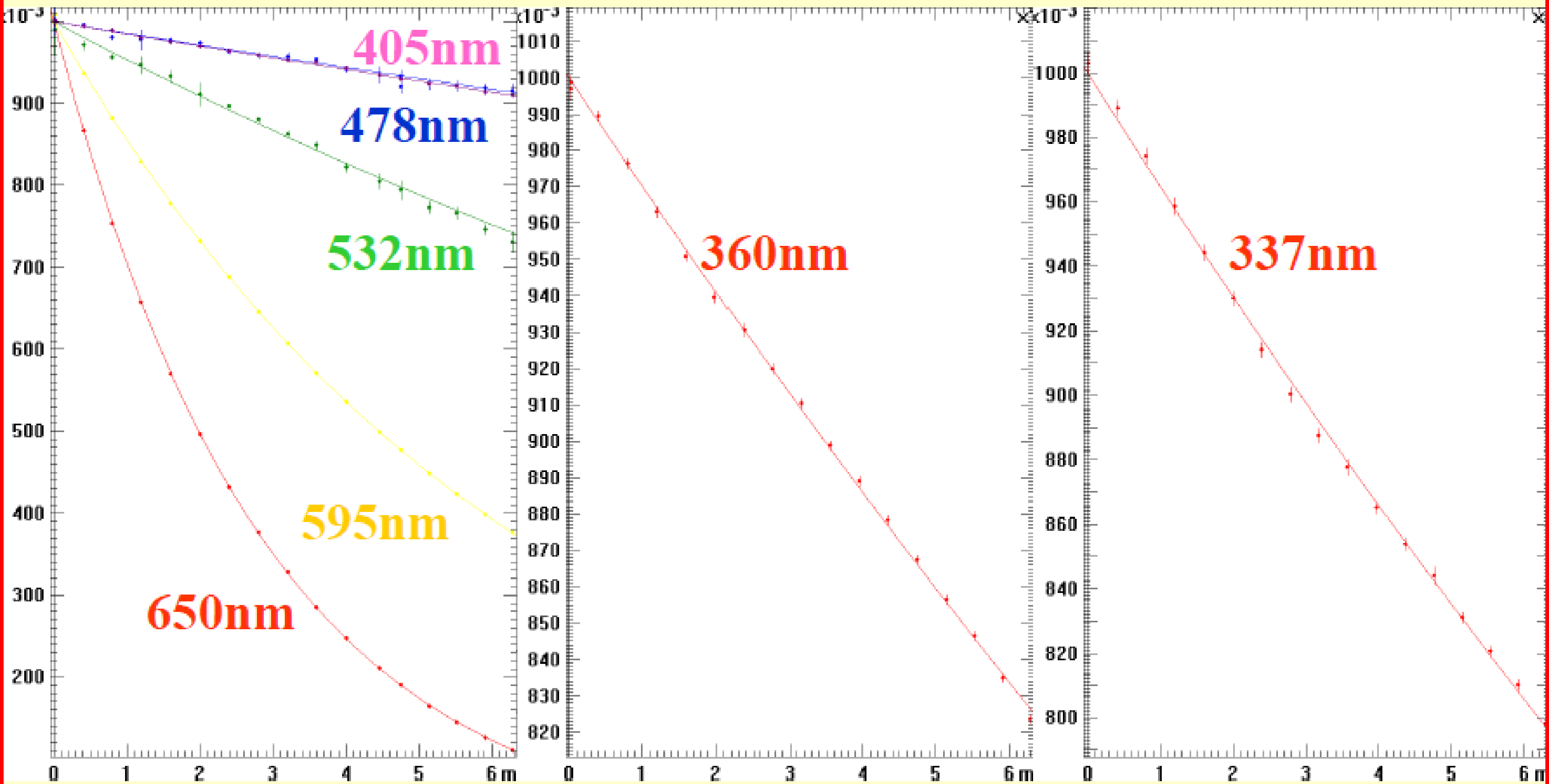
- idea based on a IMB device
- measure light intensity continuously as a function of light travel distance
- vertical pipe for quick & easy change of distance
- pipe is necessarily short (< height of lab)
- look for changes when $GdCl_3$, $Gd(NO_3)_3$, $Gd_2(SO_4)_3$ is introduced
- plastic pipe and tank (no metal effects)
- use integrating spheres and a focal lens to stabilize intensity measurements of Si photodiodes
- use laser pointers (small, cheap & good beam quality)

Experimental Setup

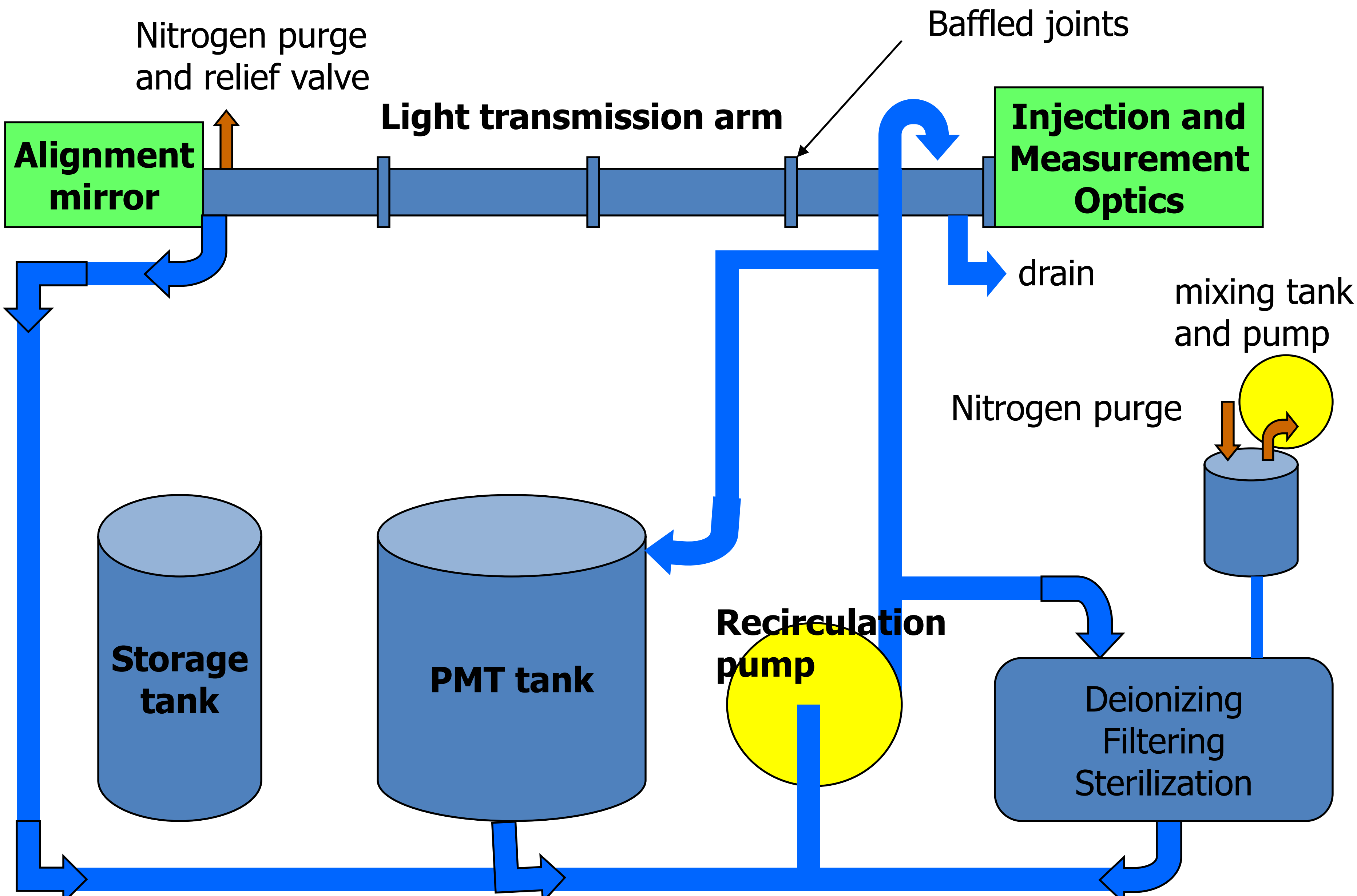


$GdCl_3$ Solution

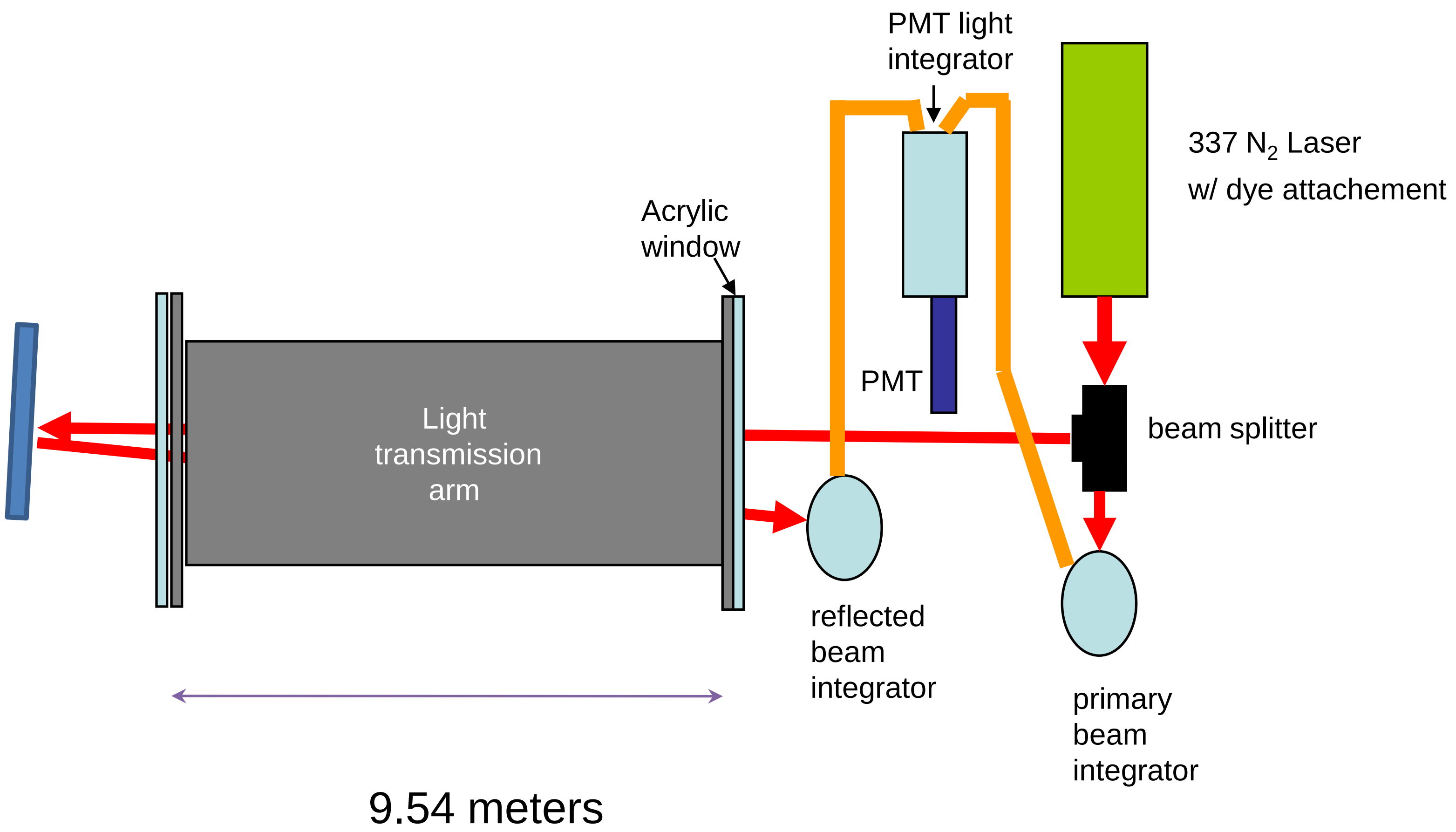
0.8% Solution: 4xGadzooks! Concentration



Testing of Material Compatibility at LLNL/UC Davis


Nitrogen purge
and relief valve
Light transmission arm
Baffled joints
Alignment mirror
Injection and Measurement Optics
drain
mixing tank
and pump
Nitrogen purge
Storage tank
PMT tank
Recirculation pump
Deionizing
Filtering
Sterilization

LLNL Test Set-Up

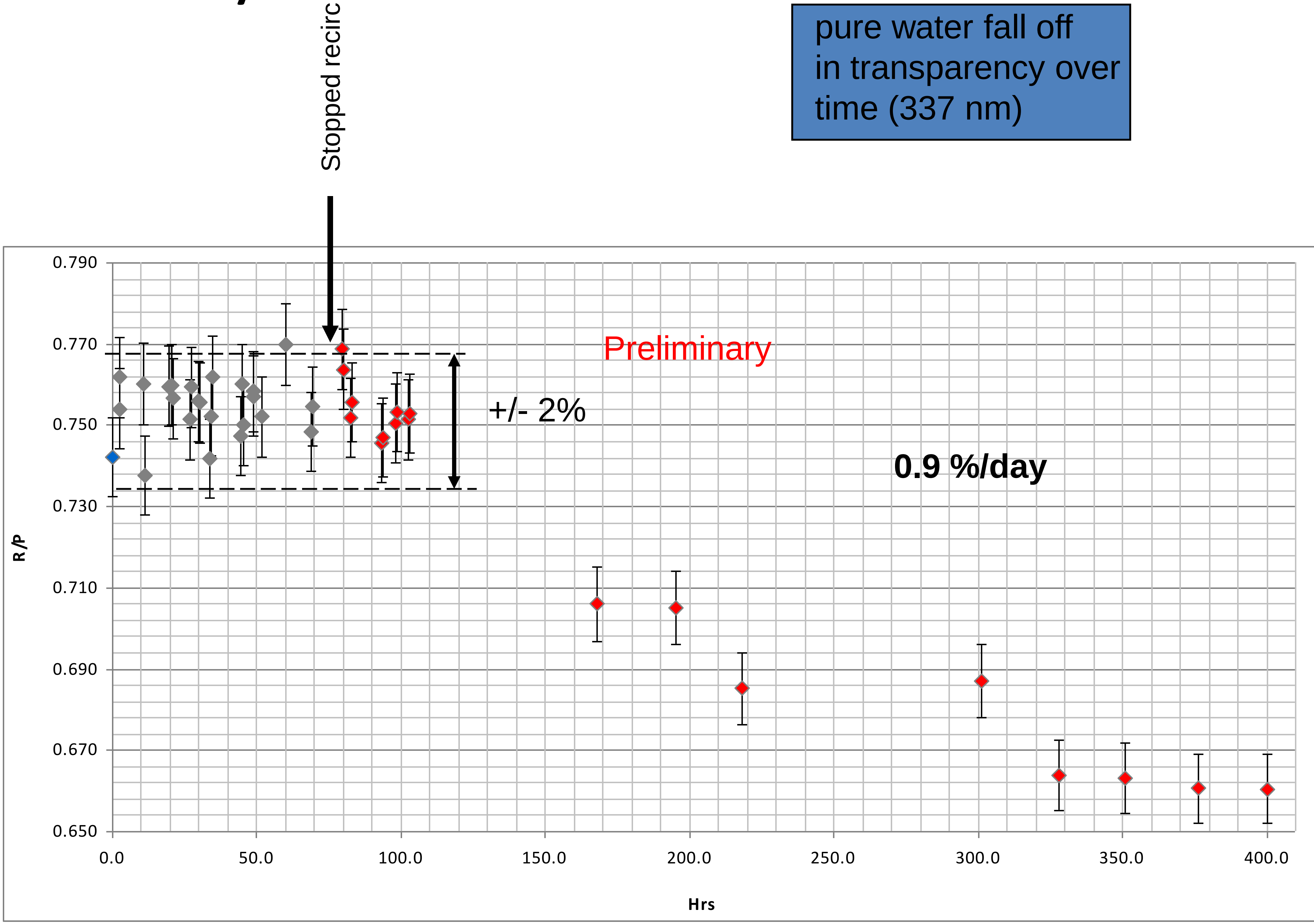


Lawrence Livermore National Laboratory

Not shown: collamators, baffles, filters

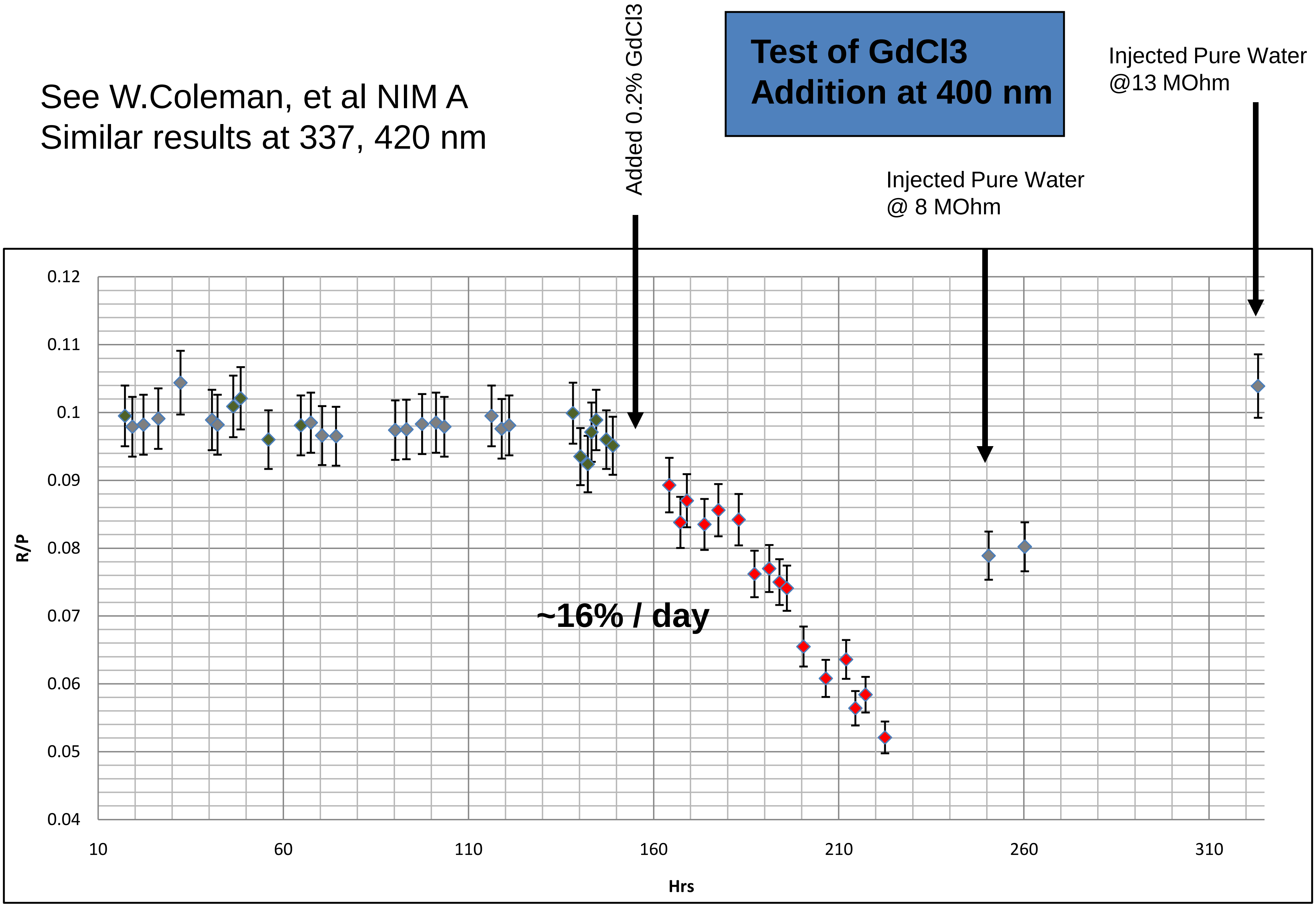
Stability of Pure Water

pure water fall off in transparency over time (337 nm)



Test of GdCl3 Addition at 400 nm

See W.Coleman, et al NIM A
Similar results at 337, 420 nm



Preliminary

Basic problem traced to stainless steel: Test with $FeCl_3$

- 10 ppm Fe^{+3} ion makes water look like ice tea. Clearly very low levels can affect transparency
- 7 ppb Fe^{+3} reduced transparency by ~30%
- Conclusion: Problem with Super-K is very likely due to reaction of Cl ions with the stainless steel tank to produce very low levels of Fe ions in water
- **Solution: Don’t use steel components!**

Currently Funded R&D LLNL: What makes good water go bad?

- Super-Kamiokande water must be continuously and cleaned – else transparency drops slowly
- Similar behavior seen in IMB (plastic walls) and SNO (acrylic walls – but much slower degradation)

REDUCING THE REQUIREMENT FOR RECIRC WILL LOWER COST OF MEGATON SCALE DETETOR, EVEN IF NO GD ADDED

Current LLNL R&D Program (PI: S.Dazeley)

- Systematic testing of materials in water and doped water over next two years
- Improve 9-meter photometer sensitivity, stability
- Goal #1: certify materials to be used in tank liners, PMT mounting, etc.
- Goal #2: verify material compatibility for Gd doping by working with UCI/IPMU group
- Help in this project needed. Student support available.

PMT considerations

	10 inch R7081	20 inch R3600
Number (25% cov)	~50000	~14000
QE	25%	20%
CE	~80%	~70%
rise time	4 ns	10 ns
Tube length	30 cm	68 cm
Weight	1150 gm	8000 gm
Vol.	~5 lt	~50 lt
pressure rating	0.7Mpa	0.6Mpa
∢ coverage/pmt	0.6 deg	1.1 deg
∢ granularity	1.0 deg	2.1 deg

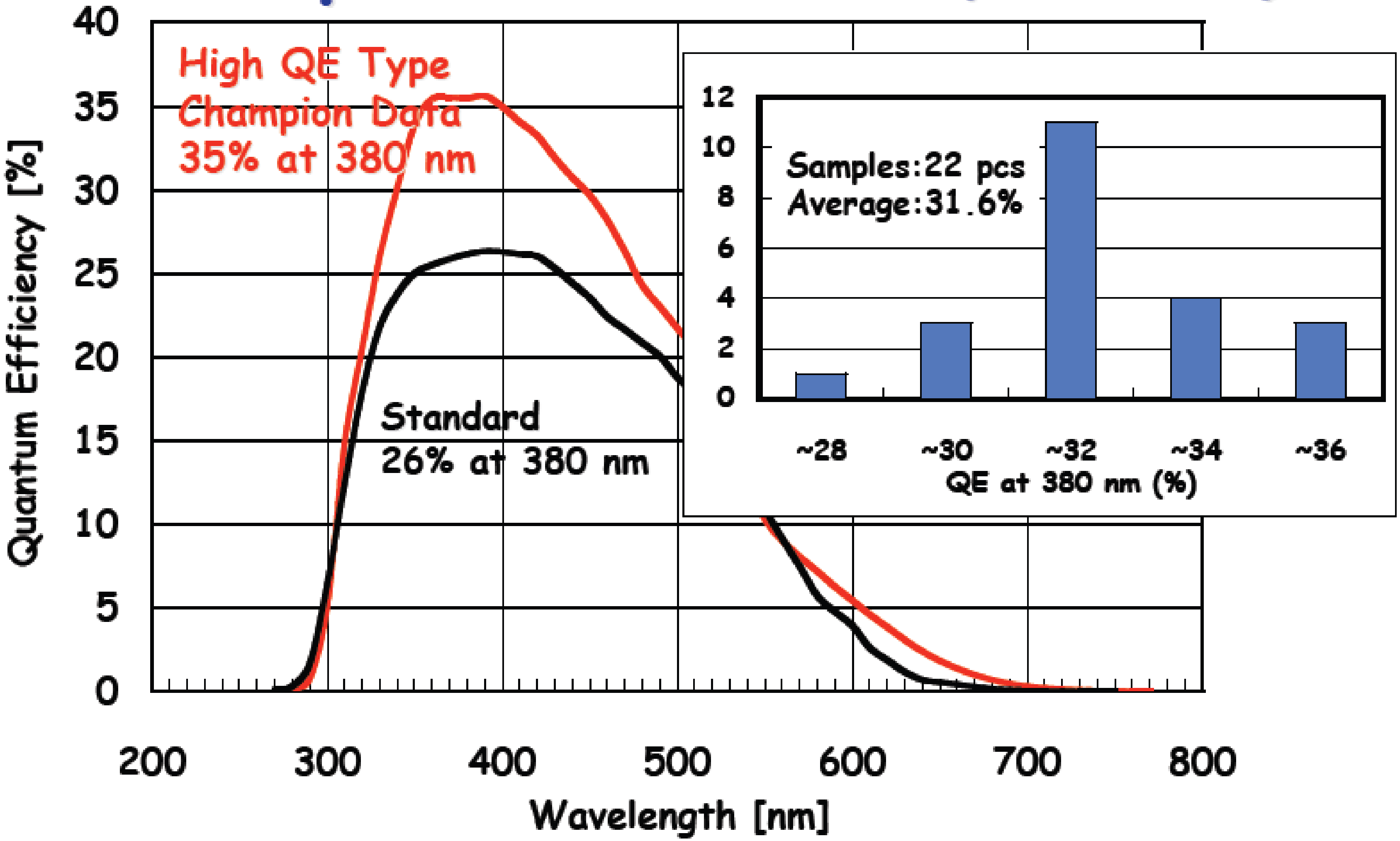
PMT: further choice

Items	Example 12-inch PMT	R7081 10-inch PMT	R5912 8-inch PMT
Diameter	300 mm	253 mm	202 mm
Effective Area	280 mm min.	220 mm min.	190 mm min.
Tube Length	330 mm	245 mm	220 mm
Dynodes	LF/10-stage	LF/10-stage	LF/10-stage
Applied Voltage	1500 V	1500 V	1500 V
GAIN	1.00E+07	1.00E+07	1.00E+07
T.T.S.(FWHM)	2.8 ns	2.9 ns	2.4 ns
P/V Ratio	2.5	2.5	2.5
Dark Counts	10,000 cps	7,000 cps	4,000 cps

NEW !

HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

Example data R7081 (10 inch)



Goal of development is 43%

M.Diwan

Pressure testing

Have 32 phototubes from Hamamatsu. Pressure vessel from BNL. Evolving testing protocol.

Hamamatsu rating is ~7atm. Tested this tube until it broke at 148 psi (~10atm)

Current/Future PMT R&D

- Working with Hamamatsu to improve PMT hardness
- improved QE will mean fewer PMTs needed for equivalent light collection
- Need to understand physics of implosion and improve PMT strength (new Wisconsin/RPI/BNL proposal to NSF)
- **Future: needed to devise and unambiguously test anti-chain reaction**

Electronics

- If we have 50,000 PMT's and use same cabling scheme as used by SK, we need <u>13,000 km of cable!</u>
- cross-talk, signal degradation, **high cost** associated with cable installation and storage
- how to improve this situation?

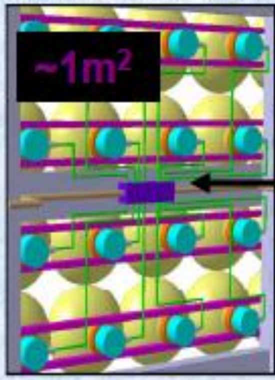
R&D : PMm2

contact: J.E.Campagne
campagne@lal.in2p3.fr

- 500k€/3yrs funded by French National Research Agency (ANR) for 2007-2010
- Participating: LAL-Orsay, IPN-Orsay, LAPP-Annecy, Photonis

PMm2 philosophy for large detectors:

Replace large PMTs (20") by groups of smaller ones (eg.12") originally proposed by Photonis Co. at NNN05



x16

"Local"

FE-ASIC

Monitoring

HV

FPGA + μC

Network Controller

"No possible local coincidence"
(low energy event 10PMs/MeV over 81000 PMs)
⇓
TRIGGER LESS DAQ

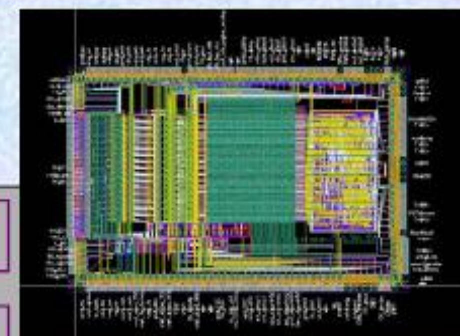
Twisted pairs cables for Clock sync. - Digitized Data - Power

"Outside"

Ethernet switches + server

DAQ

GPS receiver



*: MEMPHYS ~ 3 x 81,000 PMTs; LENA & GLACIER ~ 20,000 ÷ 30,000 PMTs

R&D : MEMPHYNO

A small scale prototype of MEMPHYS

- ~10t of water (+Gd?)
- 2x2x2m^3 HDPE tank
- Matrix of 16 12" PMTs (from PMm2 R&D) and/or other photodetectors (e.g.: X-HPX)
- muon hodoscope
  2+2 planes of OPERA-like scintillator bars

APC-Paris
LAL-Orsay
LAPP-Annecy

What's Needed Now?

Boring things needed to make sure a One Billion Dollar Project is on the Path to Assured Success

- Detector Lining and PMT mounting
- Cavern costs and stability
- further work on an <u>unambiguous</u> guarantee of PMT stability
- further development of Gd doping and material compatibility
- other work: water soluble dyes (follow up on pioneering work by SNO), waveshifter plates (IMB)

- development of electronics that can be economically used in a megaton scale water detector
- DETECTOR SOFTWARE AND OPTIMIZATION
- coordination of world-wide effort (this is happening now)

The “Vision” thing

- **Unprecedented Opportunity!**
- **A Shared Vision: Technology Choice**
- **What Will Get Us on The Road to Success?**
- **What Are Dangers on that Road?**
- **It Will be Tough**
- **Don’t Worry – Be Happy**